

Comprehensive Stroke Centers May Be Associated With Improved Survival in Hemorrhagic Stroke

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Background—Comprehensive stroke centers (CSCs) provide a full spectrum of neurological and neurosurgical services to treat complex stroke patients. CSCs have been shown to improve clinical outcomes and mitigate disparities in ischemic stroke patients. It is believed that CSCs also improve outcomes in hemorrhagic stroke.

Methods and Results—We used the Myocardial Infarction Data Acquisition System (MIDAS) database, which includes data on patients discharged with a primary diagnosis of intracerebral hemorrhage (ICH; International Classification of Diseases, Ninth Revision [ICD-9] 431) and subarachnoid hemorrhage (SAH; ICD-9 430) from all nonfederal acute care hospitals in New Jersey (NJ) between 1996 and 2012. Out-of-hospital deaths were assessed by matching MIDAS records with NJ death registration files. The primary outcome variable was 90-day all-cause mortality. The primary independent variable was CSC versus primary stroke center (PSC) and nonstroke center (NSC) admission. Multivariate logistic models were used to measure the effects of available covariates. Overall, 36 981 patients were admitted with a primary diagnosis of ICH or SAH during the study period, of which 40% were admitted to a CSC. Patients admitted to CSCs were more likely to have neurosurgical or endovascular interventions than those admitted to a PSC/NSC (18.9% vs. 4.7%; $P < 0.0001$). CSC admission was associated with lower adjusted 90-day mortality (35.0% vs. 40.3%; odds ratio, 0.93; 95% confidence interval, 0.89 to 0.97) for hemorrhagic stroke. This was particularly true for those admitted with SAH.

Conclusions—Hemorrhagic stroke patients admitted to CSCs are more likely to receive neurosurgical and endovascular treatments and be alive at 90 days than patients admitted to other hospitals. (*J Am Heart Assoc.* 2015;4:e001448 doi: 10.1161/JAHA.114.001448)

Key Words: comprehensive stroke center • intracerebral hemorrhage • subarachnoid hemorrhage

Stroke is a leading cause of death and disability in the United States. Hemorrhagic strokes, including both intracerebral hemorrhage (ICH) and subarachnoid hemorrhage (SAH), account for ≈20% of all strokes. These highly morbid conditions frequently cause death or lead to neurological disability in survivors.¹ Specialized stroke units and stroke centers have been shown to improve neurological outcomes and reduce mortality

for patients with ischemic stroke.^{2,3} High-quality medical and surgical care may also improve patient outcomes after hemorrhagic stroke. Risk-adjusted 30-day mortality has been demonstrated to be lower for patients treated at Joint Commission–certified primary stroke centers (PSCs) than nondesignated hospitals in a large cohort of Medicare beneficiaries.⁴

The Brain Attack Coalition and American Heart Association/American Stroke Association previously proposed the creation of comprehensive stroke centers (CSCs) to care for complex stroke patients, including those with intracranial bleeding.^{5,6} These specialized stroke centers would create coordinated systems of care with integrated delivery of a broad spectrum of neurological, neurosurgical, endovascular, and neurocritical care therapies above and beyond those provided at PSCs. The ultimate goal of CSC-level care is improving outcomes of patients with severe or complex strokes.

The State of New Jersey (NJ) enacted the Stroke Center Act in 2004. This legislation requires the NJ Department of Health and Senior Services (DHSS) to designate qualified hospitals that apply as CSCs or PSCs. The NJ DHSS began the application/certification process in 2007. Further details are

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*A list of the Myocardial Infarction Data Acquisition Study (MIDAS 22) Study Group can be found in the Appendix.

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available through the NJ DHSS website (<http://www.state.nj.us/health/healthcarequality/stroke/index.shtml>).

The aims of this study are 2-fold: (1) to compare the 90-day mortality rates of ICH and SAH among patients admitted to CSCs versus PSCs and nonstroke centers (NSCs) and (2) to determine whether any differences in mortality were associated with neurosurgical or endovascular treatments or temporal improvements in stroke care.

Methods

Study Design

We used the Myocardial Infarction Data Acquisition System (MIDAS) administrative database for this study.^{2,7} MIDAS includes demographic and clinical data on patients discharged with a primary diagnosis of SAH and ICH (codes 430 and 431, respectively, of the International Classification of Diseases, Ninth Revision [ICD-9], Clinical Modification) from all NJ nonfederal acute care hospitals. The database also contains records of neurosurgical and endovascular procedures, including craniotomy and craniectomy (ICD-9 code 01.2); insertion or replacement of an external ventricular drain (EVD), intracranial ventricular shunt, or intracranial pressure (ICP) monitor (ICD-9 codes 0.12, 0.22, 02.39, and 01.10); surgical clipping, repair, or occlusion of an intracranial aneurysm/vessel (ICD-9 codes 39.51, 39.52, 38.82); and endovascular embolization or occlusion of a head or neck vessel (ICD-9 code 39.72). Data for the following coexisting conditions were available: hypertension (HTN), diabetes, atrial fibrillation, and chronic kidney disease. We obtained data on out-of-hospital deaths by matching MIDAS records with NJ death registration files using previously validated linkage and consolidation software (The Link King).⁸ Out-of-state deaths were not recorded. Patients that were not readmitted within 1 year were assumed to be alive. Outcomes were assessed by a blinded automated procedure.

Study Population

MIDAS includes 4 186 339 cardiovascular admissions between 1996 and 2012, out of which 47 406 patients were admitted with ICH or SAH as the primary diagnosis. Only the first discharge record for each patient was included. Subsequent records were excluded to avoid duplicating data or introducing bias from interhospital transfers or readmission for the same events, leaving a total study population of 36 981. Patients transferred from outside emergency departments to CSCs were included in the primary analysis. A secondary analysis was conducted to assess outcomes of patients transferred to a CSC, after being admitted to a PSC/NSC for less than 24 hours, when compared to those patients that remained at the NSC/PSC. We excluded hemorrhagic

stroke patients admitted to federal hospitals or nursing homes as well as those that had their stroke during a hospital admission for another diagnosis or procedure.

Study Variables

The primary outcome variable was all-cause mortality within 90 days of hospital admission. In-hospital and cumulative (inpatient plus postdischarge) death rates at 30 and 365 days were also examined. The primary independent variable was admission to a CSC versus PSC or NSC. Covariables included patient demographics, coexisting conditions, and neurosurgical/endovascular treatments. Neither measures of hematoma size or location nor stroke severity or clinical grade were available. Each hospital in MIDAS was categorized based on its current NJ DHSS designation as CSC (13), PSC (52), or NSC (22).

Statistical Analysis

We examined differences in all-cause mortality between CSC and PSC and NSC admission for hemorrhagic stroke patients between 1996 and 2012. To adjust for available confounders, we used multivariate logistic regression models in comparing the odds of death associated with CSC versus PSC/NSC admission at 90 days. Multivariate logistic regression models were also used to compare treatments among hospital types accounting for the confounding effects of patient demographics and coexisting conditions. A Kaplan-Meier analysis was used to compare the odds of survival up to 1 year after hemorrhagic stroke. Chi-square (χ^2) tests were conducted to compare in-hospital, 30-day, 90-day, and 1-year mortality rates between CSC and PSC/NSC admissions. Two sensitivity analyses were performed: one that limited the study period to the time after NJ began the stroke center designation process (2007–2012) and the other that evaluated hospitals based on 2014 stroke center designations by The Joint Commission (TJC). Temporal trends were evaluated using linear regression models comparing annual mortality rates across hospital types assuming a linear effect of time. Statistical significance was defined as a *P* value ≤ 0.01 .

Statistical analyses were performed using SAS software (SAS Institute, Cary, NC). The institutional review boards of the NJ DHSS and the Rutgers-Robert Wood Johnson Medical School (New Brunswick, NJ) approved the study. Informed consent was not required.

Results

Patient Characteristics

There were 36 981 patients admitted between 1996 and 2012 with a primary diagnosis of ICH or SAH that were included in the primary analysis. Significant differences

Table 1. Patient Demographics and Clinical Characteristics

	CSC (N=14 788)	PSC/NSC (N=22 193)	P Value*
Age, y (mean±SD)	65.3 (17.3)	70.5 (15.9)	<0.0001
Gender: male	7104 (48.0)	10 279 (46.3)	<0.0001
Race			<0.0001
White	9499 (64.2)	16 391 (73.9)	
Black	2850 (19.3)	3433 (15.5)	
Other	2439 (16.5)	2369 (10.7)	
Payer			<0.0001
Commercial	5865 (39.7)	7037 (31.7)	
Medicare	6815 (46.1)	13 120 (59.1)	
Medicaid	537 (3.6)	588 (2.6)	
Self-pay	1519 (10.3)	1435 (6.5)	
Other	52 (0.4)	13 (0.1)	
Coexisting conditions			
Hypertension	9167 (62.0)	14 912 (67.2)	<0.0001
Diabetes	2493 (16.9)	4430 (20.0)	<0.0001
Atrial fibrillation	2155 (14.6)	3805 (17.1)	<0.0001
Renal disease	1357 (9.2)	1771 (8.0)	<0.0001
Procedures			
Craniotomy	356 (2.4)	285 (1.3)	<0.0001
EVD/ICP monitor	760 (5.1)	158 (0.7)	<0.0001
Vascular clipping	1173 (7.9)	566 (2.6)	<0.0001
Embolization	510 (3.4)	31 (0.1)	<0.0001
LOS, days (median±IQR)	7 (3 to 14)	6 (2 to 11)	<0.0001

Values within parenthesis expressed in percentage, unless otherwise specified. CSC indicates comprehensive stroke center; EVD, external ventricular drain; ICP, intracranial pressure; IQR, interquartile range; LOS, length of stay; NSC, nonstroke center; PSC, primary stroke center.

*P values are based on χ^2 tests for categorical variables and *t*-test or Wilcoxon test for continuous variables.

existed in several baseline and clinical characteristics between patients admitted to CSCs versus PSCs and NSCs (Table 1). Annual ICH volumes remained relatively constant over the study period, whereas there was an increase in admissions for SAH in recent years.

Hospital Characteristics

Eighty-seven hospitals were represented in this analysis; 13 were CSC, 52 were PSC, and 22 were NSC. Of the total study population, only 14 788 (40.0%) patients with hemorrhagic stroke were admitted to a CSC. The remaining 22 193 (60.0%) patients were admitted to either a PSC or NSC. Over time, there was an increase in the percentage of patients admitted to a CSC for both ICH and SAH (Figure 1A and 1B).

Neurosurgical Procedures

Cumulatively, neurosurgical and endovascular interventions in hemorrhagic stroke patients were performed more frequently in CSCs than PSC/NSCs (18.9% vs. 4.7%; $P<0.0001$). Hemorrhagic stroke patients were significantly more likely to undergo craniotomy or craniectomy (odds ratio [OR], 1.80; 95% confidence interval [CI], 1.55 to 2.10); insertion or replacement of an EVD, intracranial ventricular shunt, or ICP monitor (OR, 6.05; CI, 5.16 to 7.10); surgical clipping, repair, or occlusion of an intracranial aneurysm/vessel (OR, 2.98; CI, 2.69 to 3.30); and endovascular embolization or occlusion of a head or neck vessel (OR, 17.40; CI, 13.01 to 23.25) after adjusting for available covariables. When examining the association between neurosurgical and endovascular interventions and mortality, EVD/ICP monitor placement was associated with increased mortality, where both neurosurgical and endovascular clipping/repair/occlusion of aneurysm/vessels were associated with lower mortality (Table 2).

Mortality

The 90-day all-cause mortality for patients admitted with hemorrhagic stroke during the study period was 38.2%. Unadjusted in-hospital, 30-day, 90-day, and 1-year mortality rates were significantly lower for patients cared for at CSCs (Table 3). Annual 90-day mortality rates significantly declined across the study period for both patients admitted to CSCs with ICH (slope= -0.004 ; $P=0.007$) and SAH (slope= -0.005 ; $P=0.001$) and those admitted to PSCs/NSCs with SAH (slope= -0.009 ; $P=0.006$) but not ICH (slope= -0.003 ; $P=0.03$) after adjusting for case volume (Figure 2A and 2B).

After adjusting for available confounding variables, CSC admission was associated with a significant reduction in 90-day mortality after hemorrhagic stroke, when compared to patients admitted to PSCs and NSCs (OR, 0.93; CI, 0.89 to 0.97; Table 3). The reduction in adjusted mortality persisted for up to 1 year (Figure 3). Several other baseline variables were observed to have significant associations with 90-day mortality after hemorrhagic stroke (Table 2). Age, race, renal disease, and atrial fibrillation were all associated with increased mortality. Male gender and HTN was associated with a reduction in 90-day mortality.

The reduction in 90-day mortality for hemorrhagic stroke admission to CSC appeared to be driven by reductions in adjusted mortality for patients with SAH. No difference in the 90-day mortality rate was observed for patients admitted to a CSC (38.0%) versus a PSC/NSC (40.3%) with a primary diagnosis of ICH after adjusting for available confounding variables (OR, 0.98; CI, 0.93 to 1.03). CSC admission for SAH was associated with a significant reduction in adjusted risk of death (27.1% vs. 40.8%; OR, 0.73; CI, 0.66 to 0.82).

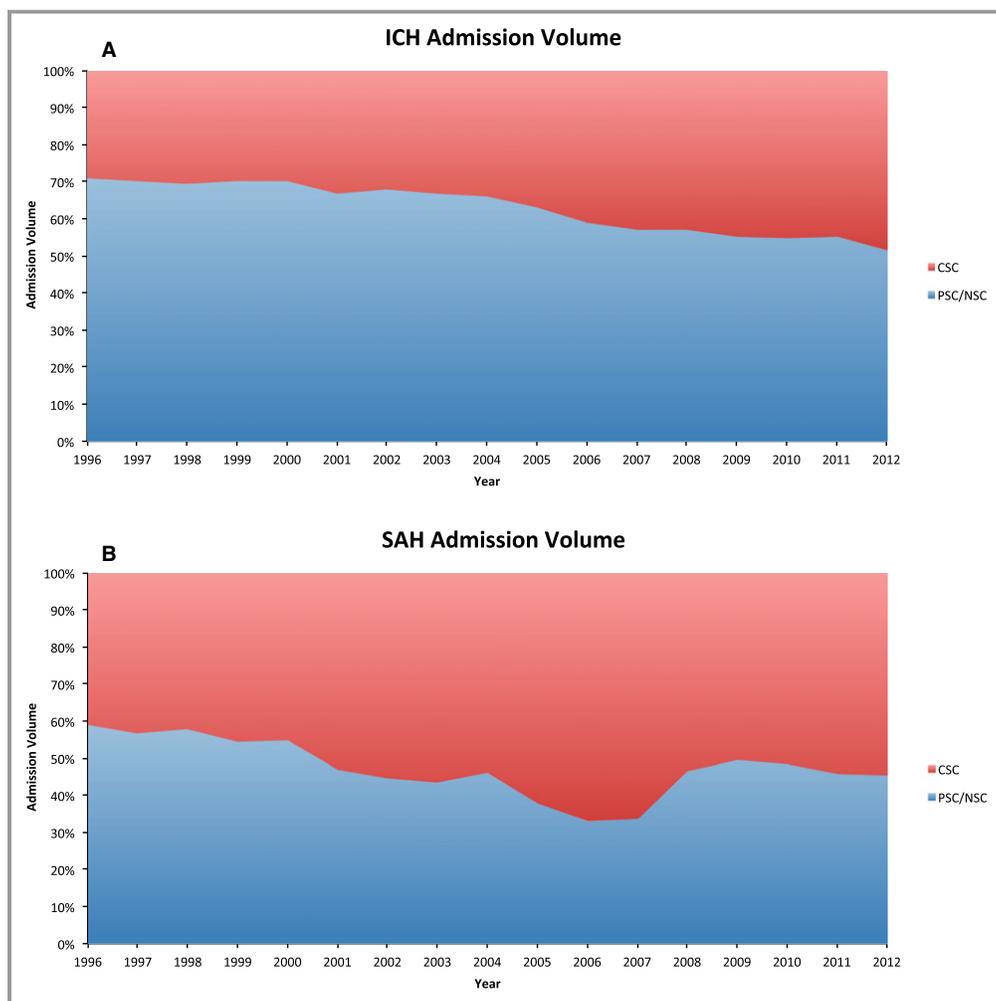


Figure 1. Temporal trends in the percentage of patients admitted to comprehensive stroke centers (CSC) versus primary stroke centers (PSC) and nonstroke centers (NSC) for patients with (A) intracerebral hemorrhage (ICH) and (B) subarachnoid hemorrhage (SAH).

Between 2007 and 2012, 12 838 patients were admitted for hemorrhagic stroke. During this time period, a nonsignificant trend toward improved survival at 90 days was observed for CSC admission (32.4%) versus PSC/NSC admission (36.9%) after adjusting for available confounding variables (OR, 0.93; CI, 0.86 to 1.01). Adjusted mortality was significantly lower at CSCs for patients admitted with SAH (OR, 0.81; CI, 0.67 to 0.98) but not ICH (OR, 0.96; CI, 0.88 to 1.04). Similarly, adjusted 90-day all cause mortality was lower for patients admitted to TJC-designated comprehensive stroke centers than other hospitals (OR, 0.87; CI, 0.81 to 0.93).

Interfacility Transfers

A secondary analysis of hemorrhagic stroke patients that were transferred from NSC/PSCs to CSCs was conducted. A total of 950 (4.1%) patients that were initially admitted to a PSC or NSC were transferred to a CSC during the initial

24 hours of hospitalization. Several baseline differences existed in patients transferred, compared to those that stayed at PSC/NSCs (Table 4). After adjusting for available covariates, patients transferred to CSCs for hemorrhagic stroke were significantly less likely to be dead at 90 days (OR, 0.64, CI, 0.54 to 0.77).

Discussion

ICH and SAH are highly morbid conditions with case fatality rates of 40% to 50%.^{9,10} The Brain Attack Coalition has advocated for creation and certification of specialized comprehensive stroke centers to manage these complex patients.⁵ Based partly on these recommendations, the NJ DHSS began a designation process for both CSC and PSC in 2007. In addition to meeting all PSC requirements, NJ DHSS-designated CSCs are expected to maintain a neurosurgical

Table 2. Adjusted Risk of Death After Hemorrhagic Stroke Admission

Effect	90-Day Mortality OR (95% CI)
CSC vs. PSC/NSC	0.93 (0.89 to 0.97)
Age	1.02 (1.02 to 1.03)
Gender: male	0.94 (0.90 to 0.98)
Race	
White vs. other	1.29 (1.20 to 1.38)
Black vs. others	1.08 (0.99 to 1.17)
Comorbidities	
Hypertension	0.76 (0.73 to 0.80)
Diabetes	0.97 (0.92 to 1.03)
Chronic kidney disease	1.51 (1.39 to 1.63)
Atrial fibrillation	1.28 (1.21 to 1.36)
Procedures	
Craniotomy	0.97 (0.81 to 1.15)
EVD/ICP monitor	1.64 (1.42 to 1.90)
Vascular clipping	0.43 (0.38 to 0.50)
Embolization	0.42 (0.33 to 0.53)

CI indicates confidence interval; CSC, comprehensive stroke center; EVD, external ventricular drain; ICP, intracranial pressure; NSC, nonstroke center; OR, odds ratio; PSC, primary stroke center.

Table 3. All-Cause Mortality After Hemorrhagic Stroke Admission

	Total (N=36 981)	CSC (N=14 788)	PSC/NSC (N=22 193)	P Value*
In-hospital	12 047 (32.6)	4620 (31.2)	7427 (33.5)	<0.001
30-day	12 578 (34.0)	4640 (31.4)	7938 (35.8)	<0.001
90-day	14 114 (38.2)	5170 (35.0)	8944 (40.3)	<0.001
1-year	15 967 (43.2)	5819 (39.3)	10148 (45.7)	<0.001

Values within parenthesis expressed in percentage, unless otherwise specified. CSC indicates comprehensive stroke center; NSC, nonstroke center; PSC, primary stroke center.

*P values are based on χ^2 tests.

team, with diagnostic and interventional neuroradiologists 24 hours per day, 7 days per week. Furthermore, CSCs are expected to offer “comprehensive” rehabilitation services, transfer agreements with PSCs, offer graduate and continuing medical education on stroke, and participate in clinical research. The availability of these specialized services is expected to lower mortality and lessen neurological disability, particularly for patients with complex strokes, including ICH and SAH.

Although stroke performance measures have been developed to monitor and improve quality of care, population-based

studies to evaluate the successful translation of evidence-based medicine into clinical practice are largely lacking.¹¹ To our knowledge, this is the largest North American cohort study evaluating the effect of comprehensive stroke care on mortality in patients with hemorrhagic stroke. In 2 recent retrospective nation-wide Japanese studies, Iihara et al. reported that CSC capabilities are associated with reduced in-hospital mortality in patients with all types of stroke.^{3,12} These observations were made by analyzing ICD-10 diagnostic codes using data from the J-ASPECT nation-wide stroke registry (obtained from the Japanese Diagnosis Procedure Combination [DPC]-based Payment System). Specifically, J-ASPECT study collaborators found in-hospital mortality reduction in patients with hemorrhagic stroke (ICH: OR=0.97; SAH: OR=0.95). These findings are similar to our own at 90 days postadmission, even after adjustment for available covariables. However, absolute mortality rates for ICH and SAH in that study were 16.8% and 28.1%, respectively, lower than our own.³ Unlike the Japanese cohorts, the observed association between CSC admission and lower adjusted odds of death appears to be driven by improved outcomes in the SAH patients in our analysis. No difference in mortality was noted in ICH patients in this cohort. Similar to our study, Iihara et al. also found increased rates of neurosurgical and endovascular procedures, such as ICH evacuation, aneurysm clipping, and aneurysm coiling, in comprehensive stroke centers, as compared to primary stroke centers.¹²

The benefits of CSC care are likely multifactorial. Specialized care in a neurological and/or neurosurgical intensive care unit (ICU) is a feature of CSCs that has been associated with reduced mortality in patients with ICH.¹³ We were not able to account for ICU type in this analysis. Similarly, we could not account for medical treatment. However, previous reports have found inadequate treatment of warfarin-associated ICH in community hospitals.¹⁴ Clinical outcomes for patients with SAH have previously been demonstrated to be better for patients treated at higher-volume centers. In a study of 16 399 patients admitted to 1546 hospitals with SAH, Cross et al. reported a significantly lower 30-day mortality rate for patients admitted to hospitals that treated over 35 SAH per year (27%), compared with those that treated less than 10 (39%).¹⁵ Similar results were observed for 9534 SAH cases treated in California from 1994 to 1997.¹⁶ Both studies may have been influenced by higher rates of endovascular therapies at high-volume centers and the transfer of patients more likely to survive to those centers.¹⁷ SAH case volumes were higher for CSCs than non-CSC hospitals in our study (Figure 1B).

In this analysis, patients with hemorrhagic stroke admitted to CSCs were, on average, 5.2 years younger than those admitted to PSC/NSCs (Table 1). This difference is likely multifactorial and may reflect an inherent bias against

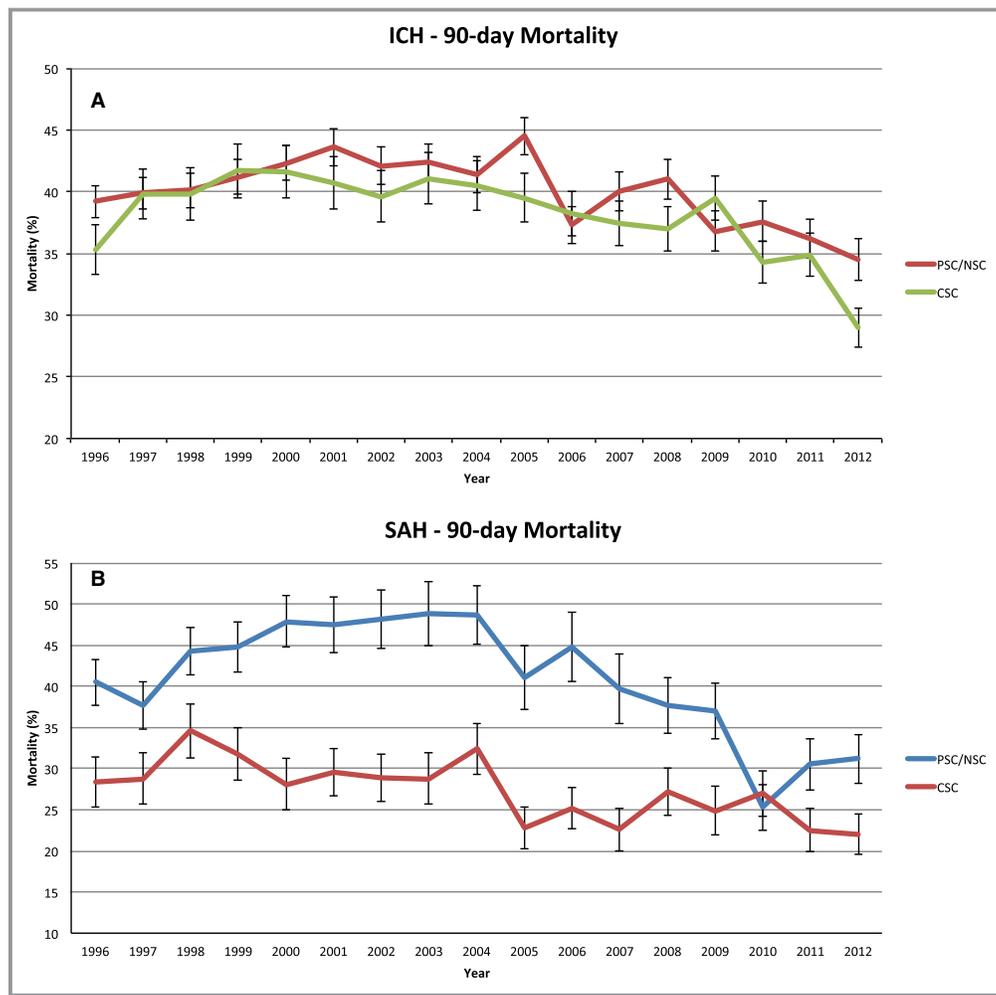


Figure 2. Temporal trends in 90-day mortality for patients admitted to comprehensive stroke centers (CSC) versus primary stroke centers (PSC) and nonstroke centers (NSC) for patients with (A) intracerebral hemorrhage (ICH) and (B) subarachnoid hemorrhage (SAH).

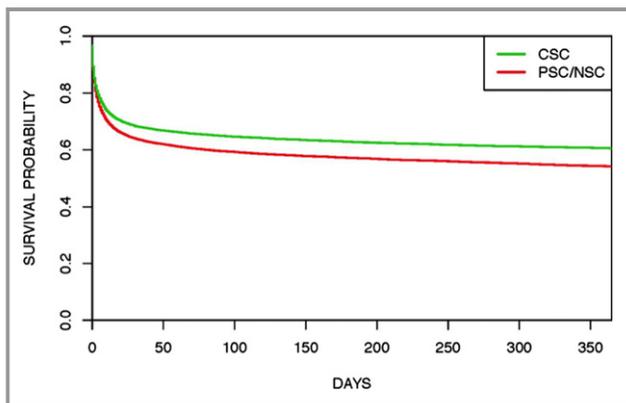


Figure 3. Kaplan-Meier survival curve for hemorrhagic stroke patients admitted to comprehensive stroke centers (CSC) versus primary stroke centers (PSC) and nonstroke centers (NSC). ICH indicates intracerebral hemorrhage; SAH, subarachnoid hemorrhage.

prehospital triage or interfacility transfer of older patients to CSCs. This is supported by the 10-year difference in age between patients transferred to CSCs versus those that remained in PSC/NCSs in our secondary analysis of interfacility transfers. Although we accounted for age in our multivariable analysis, age is likely a powerful determinant of patient selection for transfer and aggressiveness of care.

We also observed that patients treated at CSCs were significantly more likely to receive neurosurgical and/or endovascular treatment for their stroke. EVD/ICP monitor placement was associated with increased mortality, but we believe that is likely confounded by increased stroke severity, intraventricular hemorrhage, and/or hydrocephalus in these patients, for all of which we could not adjust. Both neurosurgical and endovascular clipping, repair, and/or occlusion of aneurysms or vessels, was associated with reductions in mortality. This is likely partly confounded by selection bias; however, without measures of stroke severity, it is not entirely

Table 4. Patient Demographics and Clinical Characteristics

	Transferred to CSC (N=950)	Remained at PSC/NSC (N=22 193)
Age, y (mean±SD)	60.0 (16.2)	70.5 (15.9)
Gender: male	412 (43.4)	10 279 (46.3)
Race		
White	594 (62.5)	16 391 (73.9)
Black	97 (10.2)	3433 (15.5)
Other	259 (27.3)	2369 (10.7)
Payer		
Commercial	486 (51.2)	7037 (31.7)
Medicare	318 (33.5)	13 120 (59.1)
Medicaid	39 (4.1)	588 (2.6)
Self-pay	89 (9.4)	1435 (6.5)
Other	18 (1.9)	13 (0.1)
Coexisting conditions		
Hypertension	487 (51.3)	14 912 (67.2)
Diabetes	117 (12.3)	4430 (20.0)
Atrial fibrillation	79 (8.3)	3805 (17.1)
Renal disease	81 (8.5)	1771 (8.0)
Procedures		
Craniotomy	37 (3.9)	285 (1.3)
EVD/ICP monitor	153 (16.1)	158 (0.7)
Vascular clipping	157 (16.5)	566 (2.6)
Embolization	176 (18.5)	31 (0.1)
LOS, days (median±IQR)	11 (5 to 19)	6 (2 to 11)

Values within parenthesis expressed in percentage, unless otherwise specified. CSC indicates comprehensive stroke center; EVD, external ventricular drain; ICP, intracranial pressure; IQR, interquartile range; LOS, length of stay; NSC, nonstroke center; PSC, primary stroke center.

clear. We have also analyzed a subset of patients with hemorrhagic stroke transferred from NSCs/PSCs to CSCs during the initial 24 hours of hospitalization and found a significant 90-day mortality reduction, although validity of results were also likely influenced by selection bias. Furthermore, patients transferred from outside emergency departments to CSCs were not captured.

There are several potential limitations to this study. The principal limitation is that unmeasured variables likely have contributed to some of the observed differences in mortality between the studied cohorts. It is likely that some of these unmeasured variables, such as stroke severity or neurological condition at presentation, may explain or mask some of our observed results. An additional limitation is the retrospective nature of the study, which has potential for selection and misclassification of information bias. Furthermore, we applied 2014 NJ DHSS stroke center designations to hospitals during

the study period. It is possible that some of these centers did not provide CSC-level care throughout that time. However, we believe that the majority of NJ CSCs likely provided comprehensive stroke care before the development of the state designation processes. Ten of the 13 centers received CSC designation within the first year of application review (2007). A sensitivity analysis, which included only 35% of the total population, showed a nonsignificant trend toward reduced 90-day mortality for patients admitted to CSCs, when compared to PSCs/NSCs. Furthermore, there was a similar reduction in 90-day mortality after hemorrhagic stroke when the data were analyzed using current TJC stroke center designations.

Owing to these limitations, caution should be used in interpreting the results. However, these limitations should not detract from the primary findings of the study that all-cause mortality after hemorrhagic stroke is lower in patients treated at CSCs. These observations, in addition to data from earlier studies in patients with acute ischemic stroke, lend support to the concept of regionalized stroke care and directing patients with more-complex or -severe strokes to CSCs. Despite the relatively large number of CSCs in NJ, less than half of hemorrhagic stroke patients were admitted to CSCs during the study period. This suggests a possible underutilization of available CSC care for patients with hemorrhagic stroke across the state and is likely similar in other regions.

Conclusions

In the MIDAS database, patients with hemorrhagic stroke admitted to CSCs from 1996 to 2012 had significantly lower adjusted mortality than those admitted to PSCs and NSCs. This disparity in mortality was particularly evident for SAH and appeared to hold for all time periods studied. Further study, particularly utilizing patient-level data sets to account for stroke severity, is warranted to confirm these findings.

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Appendix

Myocardial Infarction Data Acquisition Study (MIDAS 22) Group Members: Dhammika Amaratunga, PhD; Javier Cabrera, PhD; Jerry Cheng, PhD; Nora Cosgrove, RN; Alice David, MS; John B. Kostis, MD; William J. Kostis, PhD, MD; James S. McKinney, III, MD; Abel E. Moreyra, MD; John S. Pantazopoulos, MD; Davit Sargsyan, MS; and Joel Swerdel, MS, MPH.

Disclosures

None.

References

- Kunitz SC, Gross CR, Heyman A, Kase CS, Mohr JP, Price TR, Wolf PA. The pilot stroke data bank: definition, design, and data. *Stroke*. 1984;15:740–746.
- McKinney JS, Deng Y, Kasner SE, Kostis JB. Comprehensive stroke centers overcome the weekend versus weekday gap in stroke treatment and mortality. *Stroke*. 2011;42:2403–2409.
- Iihara K, Nishimura K, Kada A, Nakagawara J, Ogasawara K, Ono J, Shiokawa Y, Aruga T, Miyachi S, Nagata I, Toyoda K, Matsuda S, Miyamoto Y, Suzuki A, Ishikawa KB, Kataoka H, Nakamura F, Kamitani S. Effects of comprehensive stroke care capabilities on in-hospital mortality of patients with ischemic and hemorrhagic stroke: J-aspect study. *PLoS One*. 2014;9:e96819.
- Lichtman JH, Jones SB, Leifheit-Limson EC, Wang Y, Goldstein LB. 30-day mortality and readmission after hemorrhagic stroke among medicare beneficiaries in joint commission primary stroke center-certified and noncertified hospitals. *Stroke*. 2011;42:3387–3391.
- Alberts MJ, Latchaw RE, Selman WR, Shephard T, Hadley MN, Brass LM, Koroshetz W, Marler JR, Booss J, Zorowitz RD, Croft JB, Magnis E, Mulligan D, Jagoda A, O'Connor R, Cawley CM, Connors JJ, Rose-DeRenzy JA, Emr M, Warren M, Walker MD. Recommendations for comprehensive stroke centers: a consensus statement from the brain attack coalition. *Stroke*. 2005;36:1597–1616.
- Leifer D, Bravata DM, Connors JJ III, Hinchey JA, Jauch EC, Johnston SC, Latchaw R, Likosky W, Ogilvy C, Qureshi AI, Summers D, Sung GY, Williams LS, Zorowitz R. Metrics for measuring quality of care in comprehensive stroke centers: detailed follow-up to brain attack coalition comprehensive stroke center recommendations: a statement for healthcare professionals from the American Heart Association/American Stroke Association. *Stroke*. 2011;42:849–877.
- Kostis JB, Wilson AC, O'Dowd K, Gregory P, Chelton S, Cosgrove NM, Chirala A, Cui T. Sex differences in the management and long-term outcome of acute myocardial infarction. A statewide study. MIDAS Study Group. Myocardial Infarction Data Acquisition System. *Circulation*. 1994;90:1715–1730.
- Campbell KM, Deck D, Krupski A. Record linkage software in the public domain: a comparison of link plus, the link king, and a 'basic' deterministic algorithm. *Health Informatics J*. 2008;14:5–15.
- van Asch CJ, Luitse MJ, Rinkel GJ, van der Tweel I, Algra A, Klijn CJ. Incidence, case fatality, and functional outcome of intracerebral haemorrhage over time, according to age, sex, and ethnic origin: a systematic review and meta-analysis. *Lancet Neurol*. 2010;9:167–176.
- Nieuwkamp DJ, Setz LE, Algra A, Linn FH, de Rooij NK, Rinkel GJ. Changes in case fatality of aneurysmal subarachnoid haemorrhage over time, according to age, sex, and region: a meta-analysis. *Lancet Neurol*. 2009;8:635–642.
- Reeves MJ, Parker C, Fonarow GC, Smith EE, Schwamm LH. Development of stroke performance measures: definitions, methods, and current measures. *Stroke*. 2010;41:1573–1578.
- Iihara K, Nishimura K, Kada A, Nakagawara J, Toyoda K, Ogasawara K, Ono J, Shiokawa Y, Aruga T, Miyachi S, Nagata I, Matsuda S, Ishikawa KB, Suzuki A, Mori H, Nakamura F. The impact of comprehensive stroke care capacity on the hospital volume of stroke interventions: a nationwide study in Japan: J-aspect study. *J Stroke Cerebrovasc Dis*. 2014;23:1001–1018.
- Diringner MN, Edwards DF. Admission to a neurologic/neurosurgical intensive care unit is associated with reduced mortality rate after intracerebral hemorrhage. *Crit Care Med*. 2001;29:635–640.
- Liotta EM, Garg RK, Temes RE, John S, Lee VH, Bleck TP, Prabhakaran S. Warfarin-associated intracerebral hemorrhage is inadequately treated at community emergency departments. *Stroke*. 2012;43:2503–2505.
- Cross DT III, Tirshwell DL, Clark MA, Tuden D, Derdeyn CP, Moran CJ, Dacey RG Jr. Mortality rates after subarachnoid hemorrhage: variations according to hospital case volume in 18 states. *J Neurosurg*. 2003;99:810–817.
- Johnston SC. Effect of endovascular services and hospital volume on cerebral aneurysm treatment outcomes. *Stroke*. 2000;31:111–117.
- Bederson JB, Connolly ES Jr, Batjer HH, Dacey RG, Dion JE, Diringner MN, Diringner JE Jr, Harbaugh RE, Patel AB, Rosenwasser RH. Guidelines for the management of aneurysmal subarachnoid hemorrhage: a statement for healthcare professionals from a special writing group of the Stroke Council, American Heart Association. *Stroke*. 2009;40:994–1025.